Note: The number in parentheses at the end of each definition indicates the page number in this book where the term first appears.

A

acceleration vector quantity representing the change in velocity (magnitude and/or direction) per unit time; non-uniform motion (23)

- **acceleration due to gravity** constant acceleration of an object falling near Earth's surface (54)

activity (decay rate) number of nuclei in a sample that decay within a given time (812)

alpha radiation emission of a helium nucleus; symbol is α (797)

altitude elevation of the ground above sea level (221)

ampere flow of 1 C of charge past a point in a conductor in 1 s (602)

amplitude of oscillation maximum displacement of a body from its equilibrium position during oscillatory motion (355)

angle of diffraction angle formed between the perpendicular bisector and the straight line to a nodal or antinodal point on the interference pattern (689)

angle of incidence angle formed between the incident ray and the normal line (654)

angle of reflection angle formed between the reflected ray and the normal line (654)

angle of refraction angle formed between the normal line and the refracted ray (666)

antimatter form of matter that has a key property, such as charge, opposite to that of ordinary matter (804)

antinode point of interaction between waves on a spring or other medium at which only constructive interference occurs; in a standing wave, antinodes occur at intervals of $\frac{1}{2}\lambda$; in an interference pattern, antinodes occur at path difference intervals of whole wavelengths (417)

armature (rotor) fundamental component of a simple DC electric motor consisting of a rotating loop of conducting wire on a shaft (608)

artificial satellite artificially created object intended to orbit Earth or other celestial body to perform a variety of tasks; includes weather, communication, observation, science, broadcast, navigation, and military satellites (284)

at rest not moving; stationary (13)

atomic mass number number of nucleons in the nucleus, $Z + N$; symbol is A (790)

atomic mass unit exactly $\frac{1}{12}$ of the mass of the carbon-12 atom; symbol is u, where $1\ \text{u} = 1.660\ 539 \times 10^{-27}$ kg (791)

atomic number number of protons in a nucleus; symbol is Z (790)

axis of rotation imaginary line that passes through the centre of rotation perpendicular to circular motion (242)

axle shaft on which a wheel rotates (242)

B

ballistic pendulum type of pendulum used to determine the speed of bullets before electronic timing devices were invented (483)

baryon hadron with half-integer spin (842)

becquerel unit of activity equal to 1 decay per second; unit is Bq (812)

beta-negative decay nuclear decay involving emission of an electron; symbol is β^- (802)

beta-positive decay nuclear decay involving emission of a positron; symbol is β^+ (805)

beta radiation emission of a high-energy electron; symbol is β (797)

binding energy net energy required to liberate all of the protons and neutrons in a nucleus (793)

blackbody object that completely absorbs any light energy that falls on it (705)

blackbody radiation curve graph of the intensity of light emitted versus wavelength for an object of a given temperature (705)

Bohr radius radius of the smallest orbit in a hydrogen atom (774)

boson particle with integer spin (842)

bright fringe (antinodal line) region of constructive interference (686)

bubble chamber device that uses trails of bubbles in a superheated liquid to show the paths of charged particles (831)

C

capacitor two conductors, holding equal amounts of opposite charges, placed near one another without touching (642)

Cartesian method method commonly used to show direction for vector quantities in two dimensions; the positive x-axis is at 0° and angles are measured by moving counterclockwise about the origin (78)

cathode ray free electrons emitted by a negative electrode (754)

central maximum line of antinodes along the perpendicular bisector of the line joining the point sources (426)

centre of curvature (C) point in space representing the centre of the sphere from which a curved mirror was cut (657)

centre of mass point where the total mass of an object can be assumed to be concentrated (492)

centripetal acceleration acceleration acting toward the centre of a circle (244)

centripetal force force acting toward the centre of a circle causing an object to move in a circular path (244)

charge migration movement of electrons in a neutral object where one side of the object becomes positive and the other side becomes negative (520)

charge shift movement of electrons in an atom where one side of an atom becomes positive and the other side becomes negative (521)

charging by induction process of charging an object by first polarizing it by induction and then retaining the charge by grounding (521)

closed pipe (closed tube) pipe closed at one end; the longest

wavelength that can resonate in a closed pipe is four times the length of the pipe (419)

closed-pipe (closed-tube) resonance if an antinode occurs at the open end of a pipe, a point of resonance (resulting from constructive interference) occurs at the open end of the pipe, and the sound appears to be amplified (419)

cloud chamber device that uses trails of droplets of condensed vapour to show the paths of charged particles (830)

collinear along the same straight line, either in the same or in opposite directions (71)

- **non-collinear** not along the same straight line (80)

collision interaction between two objects involving an impulse with a large F_{net} and a very short Δt (469)

- **elastic collision** collision in which the total kinetic energy of a system is conserved ($E_{k_i} = E_{k_f}$) (481)
- **inelastic collision** collision in which the total kinetic energy of a system is not conserved ($E_{k_i} \neq E_{k_f}$) (483)

colour quantum property related to the strong nuclear force (848)

commutator fundamental component of a simple DC electric motor consisting of a mechanism for maintaining a properly polarized connection to the moving coil in a motor or generator (608)

components perpendicular parts (R_x and R_y) into which a vector can be separated (77)

Compton effect change in wavelength of the scattered X-ray photon (721)

Compton scattering scattering of an X ray by an electron (721)

conduction process of charging an object through the direct transfer of electrons when a charged object touches a neutral object (519)

conductor material in which electrons in the outermost regions of the atom are free to move (513)

conservative forces forces that act within systems but do not change their mechanical energy; includes gravity and elastic forces (314)

- **non-conservative forces** forces, such as friction, and forces applied from outside a system, that cause the energy of the system to change so that energy is not conserved (319)

converging lens lens that refracts rays travelling parallel to the principal axis inward to intersect at the principal focus (677)

converging mirror concave reflecting surface that causes parallel light rays to converge after being reflected (657)

coulomb SI unit for electric charge (C) (529)

Coulomb's law magnitude of the force of electrostatic attraction or repulsion ($|\vec{F}_e|$) is directly proportional to the product of the two charges q_1 and q_2 ($|\vec{F}_e| \propto q_1 q_2$) and inversely proportional to the square of the distance between their centres r (529)

crest region where the medium rises above the equilibrium position (394)

critical angle for any two media, the size of the incident angle for which the angle of refraction is 90° (672)

current quantity of charge that flows through a wire in a given unit of time (602)

cycle one complete back-and-forth motion or oscillation (249)

cyclotron particle accelerator Particle accelerator in which the magnetic field perpendicular to the paths of the charged particles makes them follow circular paths within two hollow semicircular electrodes. An alternating voltage accelerates the charged particles each time they cross the gap between the two electrodes. The radius of each particle's path increases with its speed, so the accelerated particles spiral toward the outer wall of the cyclotron. (841)

D

dark fringe (nodal line) region of destructive interference (686)

daughter element element produced by a decay process (799)

decay constant probability of a nucleus decaying in a given time; symbol is λ (811)

diffraction change in shape and direction of a wave front as a result of encountering a small opening or aperture in a barrier, or a corner (685)

diffraction grating sheet of glass or plastic etched with a large number of parallel lines; when light is incident on the grating, each line or slit acts as one individual light source (692)

diffuse (irregular) reflection behaviour describing parallel incident rays scattered in different directions when reflected from an irregular surface (653)

dispersion separation of white light into its components (675)

displacement straight line between initial and final positions; includes magnitude and direction (7)

distance length of the path taken to move from one position to another (7)

diverging lens lens that refracts rays travelling parallel to the principal axis outward to appear as though they have originated at a virtual principal focus (677)

diverging mirror convex reflecting surface that causes parallel light rays to spread out after being reflected (657)

diverging ray ray that spreads out as it moves away from the origin (397)

domain region of a material in which the magnetic fields of most of the atoms are aligned (589)

Doppler effect apparent change in frequency and wavelength of a wave that is perceived by an observer moving relative to the source of the wave (429)

drift tube particle accelerator particle accelerator in which alternating voltage accelerates charged particles through a series of electrodes shaped like open tubes; particles are always attracted to the next tube in the line (841)

dynamics branch of mechanics dealing with the cause of motion (126)

E

eccentricity degree to which an ellipse is elongated; number between 0 and 1, with 0 being a perfect circle and 1 being a parabola (269)

efficiency ratio of the energy output to the energy input of any system (324)

elastic potential energy energy resulting from an object being altered from its standard shape, without permanent deformation (300)

electric field lines lines drawn to represent the electric field; density of the lines represents the magnitude of the electric field (554)

electric potential (voltage) change in electric potential energy stored per unit charge; symbol is V (564)

electric potential difference change in electric potential experienced by a charge moving between two points in an electric field (565)

electric potential energy energy stored in a system of two charges a certain distance apart; change in electric potential energy equals work done to move a small charge ($\Delta E_p = W$) (561)

electromagnet magnet having its magnetic field produced by electric current flowing through a coil of wire (588)

electromagnetic radiation (EMR) radiant energy in the form of a wave produced by the acceleration of electrons or other charged particles; does not require a material medium; can travel through a vacuum (636)

electron volt change in energy of an electron when it moves through a potential difference of 1 V; unit is eV (564)

electrostatics study of electric charges at rest (513)

electroweak force fundamental force that combines the electromagnetic force and the weak nuclear force (848)

elementary unit of charge charge on a proton; symbol is e (762)

ellipse elongated circle; consists of two foci, a major, and a minor axis (269)

energy ability to do work (292)

energy level discrete and quantized amount of energy (773)

equilibrium position rest position or position of a medium from which the amplitude of a wave can be measured (394)

excited state any energy level higher than the ground state (775)

F

femto metric prefix meaning 10^{-15} (790)

fermion particle with half-integer spin (842)

ferromagnetic having magnetic properties, such as those of iron (589)

field three-dimensional region of influence surrounding an object (200)

- **electric field** three-dimensional region of electrostatic influence surrounding a charged object (641)
- **gravitational field** region of influence surrounding any object that has mass (200)
- **magnetic field** three-dimensional region of magnetic influence surrounding a magnet, in which other magnets or magnetic substances are affected by magnetic forces (584)

first order maximum line of antinodes resulting from a one-wavelength phase shift (427)

fission reaction in which a nucleus with $A > 120$ splits into smaller nuclei that have greater binding energy per nucleon (818)

focal length (f) distance from the vertex to the focal point, measured along the principal axis; related to the radius of curvature by $f = r/2$ (657)

force quantity measuring a push or a pull on an object; measured in newtons (127)

- **action force** force initiated by object A on object B (160)
- **action-at-a-distance force** force that acts even if the objects involved are not touching (200)
- **applied force** force exerted directly on an object by a person; symbol is $\vec{F}_{app}$ (130)
- **gravitational force** attractive force between any two objects due to their masses; symbol is $\vec{F}_g$ (196)
- **net force** vector sum of two or more forces acting simultaneously on an object; symbol is $\vec{F}_{net}$ (131)
- **normal force** force on an object that is perpendicular to a common contact surface; symbol is $\vec{F}_N$ (130)
- **reaction force** force exerted by object B on object A (160)
- **restoring force** force acting opposite to the displacement to move an object back to its equilibrium position (353)
- **strong nuclear force** force that binds together the protons and neutrons in a nucleus (793)
- **weak nuclear force** fundamental force that acts on electrons and neutrinos (804)

forced frequency frequency at which an external force is applied to a resonating object (382)

Fraunhofer line dark line in the spectrum of the Sun (773)

free-body diagram vector diagram of an object in isolation showing all the forces acting on it (129)

free fall situation in which the only force acting on an object that has mass is the gravitational force (226)

frequency number of cycles per second measured in hertz (Hz) (249)

friction force that opposes either the motion of an object or the direction the object would be moving in if there were no friction; symbol is $\vec{F}_f$ (169)

fundamental forces basic forces of nature that physicists think underlie all interactions in the universe (194)

fundamental frequency lowest frequency produced by a particular instrument; corresponds to the standing wave having a single antinode, with a node at each end of the string (422)

fusion reaction in which two low-mass nuclei combine to form a single nucleus with $A < 60$; the resulting nucleus is more tightly bound (818)

G

gamma decay emission of a high-energy photon by a nucleus; symbol is γ (806)

gamma radiation emission of a high-energy photon; symbol is γ (797)

generator effect (electromagnetic induction) production of electricity by magnetism (611)

gluon mediating particle for the strong nuclear force (838)

grand unified theory quantum theory unifying the electromagnetic, strong nuclear, and weak nuclear forces (849)

gravimeter sensitive instrument used to detect small variations in the magnitude of the gravitational field strength on Earth's surface (222)

gravitational field strength gravitational force per unit mass at a specific location (201)

gravitational mass mass measurement based on comparing the known weight of one object to the unknown weight of another object (199)

gravitational potential energy energy of an object due to its position above the surface of Earth (295)

graviton hypothetical mediating particle for the gravitational force (838)

gravity assist use of the gravitational force exerted by celestial bodies to reduce interplanetary travel times (214)

gray dose of ionizing radiation that delivers 1 J of energy to each kilogram of material absorbing the radiation; unit is Gy (809)

ground state lowest possible energy level (774)

grounding process of transferring charge to and from Earth (521)

H

hadron subatomic particle that interacts via the strong nuclear force (842)

half-life time it takes for half of the radioactive nuclei in a sample to decay (812)

Heisenberg's uncertainty principle it is impossible to know both the position and momentum of a particle with unlimited precision at the same time (735)

high tide highest level of ocean water that occurs near Earth's coastlines (211)

Hooke's Law relationship where the stretch produced by a force applied to a spring is proportional to the magnitude of the force (299)

horsepower (hp) unit used to identify the power output of motors, mainly in the automotive industry (324)

Huygens' Principle model of wave theory, which predicted the motion of a wave front as being many small point sources propagating outward in a concentric circle at the same speed as the wave itself (684)

I

image attitude orientation characteristic of an image, whether erect or inverted (656)

image position where the image forms relative to the surface of the mirror (656)

image type distinction between real and virtual images (656)

- **real image** image from which light rays come; can be formed on a diffusely reflecting surface or screen (654)
- **virtual image** image from which light rays appear to come; cannot be formed on a non-reflective surface or screen (654)

impulse product of the net force on an object and the time interval during an interaction (457)

incandescent glowing with heat (704)

induction movement of charge caused by an external charged object (520)

inertia property of an object that resists acceleration (138)

inertial mass mass measurement based on the ratio of a known net force on an object to the acceleration of the object (148)

insulator material in which the electrons are tightly bound to the nucleus and are not free to move within the substance (513)

interference effect of two pulses (or two waves) crossing within a medium; the medium takes on a shape that is different from the shape of either pulse alone (411)

- **constructive interference** overlap of pulses to create a pulse of greater amplitude (412)
- **destructive interference** overlap of pulses to create a pulse of lesser amplitude (412)

interference fringes fixed interference pattern of light and dark bands (686)

interference pattern pattern of maxima and minima resulting from the interaction of waves, as crests and troughs overlap while the waves move through each other (425)

ionization energy energy required to remove an electron from an atom (775)

isotopes atoms that have the same number of protons, but different numbers of neutrons (791)

K

kinematics branch of physics that describes motion (6)

kinetic energy energy due to the motion of an object; symbol is E_k (302)

kinetic friction force exerted on an object in motion that opposes the motion of the object as it slides on another object; symbol is $\vec{F}_{f_{kinetic}}$ (176)

- **coefficient of kinetic friction** proportionality constant relating $\vec{F}_{f_{kinetic}}$ and F_N (183)

L

latitude angular distance north or south of the equator (221)

law of conservation of charge net charge of an isolated system is conserved (517)

law of conservation of energy within an isolated system, energy may be transferred from one object to another or transformed from one form to another, but it cannot be increased nor decreased (312)

law of conservation of momentum momentum of an isolated system is constant (473)

law of magnetism like magnetic ends repel and unlike ends attract each other

law of reflection angle of reflection is equal to the angle of incidence and is in the same plane (654)

Lenz's law direction of a magnetically induced current is such as to oppose the cause of the current (618)

lepton subatomic particle that does not interact via the strong nuclear force (842)

low tide lowest level of ocean water that occurs near Earth's coastlines (211)

M

magnification relationship of the size of the image to the size of the object (656)

mass defect difference between the sum of the masses of the separate nucleons and the mass of the nucleus; symbol is Δm (794)

maximum (line of antinodes) line of points linking antinodes that occur as the result of constructive interference between waves (426)

Maxwell's Equations series of equations that summarized the relationships between electricity and magnetism, and predicted the existence of electromagnetic waves and their propagation through space (642)

mechanical energy sum of potential and kinetic energies; symbol is E_m (306)

mechanical resonance increase in amplitude of oscillation of a system as a result of a periodic force whose frequency is equal or very close to the resonant frequency of the system (382)

mechanics study of kinematics, statics, and dynamics (306)

medium material, for example, air or water through which waves travel; the medium does not travel with the wave (394)

meson hadron with integer spin (842)

minimum (nodal line) line of points linking nodes that occur as the result of destructive interference between waves (426)

mirror equation equation relating the focal length of a curved mirror to the image and object distances (662)

momentum product of the mass of an object and its velocity (449)

momentum (of a system) sum of the momenta of all the objects in the system (470)

motor effect force deflecting force acting on a charged particle moving in a magnetic field (593)

muon unstable subatomic particle having many of the properties of an electron but a mass 207 times greater (842)

N

natural satellite naturally formed body that revolves around a planet (moon) (273)

navigator method method commonly used to show direction for vector quantities in two dimensions; uses compass bearings north [N], south [S], east [E], and west [W] to identify vector directions (78)

net charge sum of all electric charges in the system (517)

neutrino extremely small neutral subatomic particle; symbol is ν (804)

neutron neutral particle found in nuclei (790)

neutron number number of neutrons in the nucleus; symbol is N (790)

Newton's first law of motion an object will continue either being at rest or moving at constant velocity unless acted upon by an external non-zero net force (139)

Newton's law of universal gravitation Any two objects, A and B, in the universe exert gravitational forces of equal magnitude but opposite direction on each other. The forces are directed along the line joining the centres of both objects. (204)

Newton's second law of motion when an external non-zero net force acts on an object, the object accelerates in the direction of the net force; the magnitude of the acceleration is directly proportional to the magnitude of the net force and inversely proportional to the mass of the object (148)

Newton's third law of motion if object A exerts a force on object B, then B exerts a force on A that is equal in magnitude and opposite in direction (161)

node (nodal point) point on a spring or other medium at which only destructive interference occurs; in a standing wave, a point that never vibrates between supercrests and supertroughs; in a standing wave, nodes occur at intervals of $\frac{1}{2}\lambda$; in an interference pattern, nodes occur at path difference intervals of $\frac{1}{2}\lambda$ (417)

normal line imaginary line drawn perpendicular to the reflecting surface (652)

nucleon proton or neutron (790)

nucleosynthesis formation of elements by the fusion of lighter elements (823)

O

open pipe (open tube) pipe opened at both ends; the longest wavelength that can resonate in an open pipe is twice the length of the pipe (424)

optical fibre central core of glass with a refractive index of approximately 1.5, surrounded by a cladding material of a slightly lower refractive index (671)

orbital probability distribution of an electron in an atom (783)

orbital period time required for a planet to make one full orbit; may be measured in Earth days (271)

orbital perturbation irregularity or disturbance in the predicted orbit of a planet (282)

orbital radius distance between the centre of the ellipse and the planet; average orbital radius corresponds to the semi-major axis (269)

origin reference point (6)

oscillation repetitive back-and-forth motion (344)

oscillatory motion motion in which the period of each cycle is constant (344)

overtone any frequency of vibration of a string that may exist simultaneously with the fundamental frequency (423)

P

parent element original element in a decay process (799)

particle discrete unit of matter having mass, momentum, and the ability to carry an electric charge (639)

alpha particle two protons and two neutrons bound together to form a stable particle (497)

beta particle electron emitted by a nucleus; symbol is β (802)

fundamental particle particle that cannot be divided into smaller particles; an elementary particle (836)

mediating particle virtual particle that carries one of the fundamental forces (837)

strange particle particle that interacts primarily via the strong nuclear force yet decays only via the weak nuclear force (845)

virtual particle particle that exists for such a short time that it is not detectable (837)

particle model describes EMR as a stream of tiny particles radiating outward from a source (639)

path length distance between a point source and a chosen point in space (688)

difference in path length difference between two path lengths, each measured from a different origin and extending to a common point in space (688)

period time required for an object to make one complete oscillation (cycle); measured in s/cycle (249)

phase shift result of waves from one source having to travel farther to reach a particular point in the interference pattern than waves from another source (426)

photoelectric effect emission of electrons when a metal is illuminated by short wavelengths of light (712)

photoelectron electron emitted from a metal because of the photoelectric effect (712)

photon (from the Greek word meaning "light") quantum of light; discrete packet of energy associated with an electromagnetic field (640)

pion unstable subatomic particle with a mass roughly 270 times that of an electron (842)

Planck's formula light comes in quanta of energy that can be calculated using the equation $E = nhf$ (705)

plane mirror smooth, flat, reflecting surface (654)

plane polarized light light resulting from polarization, in which only one plane of the electric field is allowed to pass through a filter (696)

planetary model atomic model that has electrons orbiting a nucleus (768)

plasma highly ionized gas containing nearly equal numbers of free electrons and positive ions (522)

point of incidence point at which the incident ray contacts a polished, reflecting surface and is reflected from the surface as the reflected ray (652)

point source single point of disturbance that generates a circular wave (395)

polarization production of a state in which the plane of the electric field for each electromagnetic wave occurs only in one direction (696)

polarizing filter filter that allows only one plane of the electric field to pass through it; plane polarized EMR emerges (696)

position straight-line distance between the origin and an object's location; includes magnitude and direction (6)

positron antielectron; positively charged particle with its other properties the same as those of an electron; symbol is e^+ or ${}^{0}_{1}\beta$ (804)

potential energy energy that is stored and held in readiness; includes gravitational and elastic potential energies; symbol is E_p

power rate of doing work (324)

primary cosmic rays high-energy particles that flow from space into Earth's atmosphere (841)

principal axis (PA) imaginary line drawn through the vertex, perpendicular to the surface of the curved mirror at this point (657)

principal focal point (F) point where light rays parallel to and close to the principal axis converge, or appear to diverge from, after being reflected (657)

principal quantum number quantum number that determines the size and energy of an orbit (774)

principle of superposition displacement of the combined pulse at each point of interference is the sum of the displacements of the individual pulses (412)

projectile object released or thrown into the air (54)

projectile motion motion in a vertical plane (54)

proton positively charged particle found in all nuclei (790)

proton–proton chain fusion process in which four hydrogen nuclei combine to form a helium nucleus (821)

pulse disturbance of short duration in a medium; usually seen as the crest or trough of a wave (401)

compression pulse region where the coils of a spring are more tightly compressed (404)

rarefaction pulse region where the coils of a spring are more widely spaced (404)

transverse pulse pulse in which the coils of the spring move at right angles to the direction of the pulse's motion (401)

Q

quanta discrete units of energy (638)

quantized limited to whole multiples of a basic amount (quantum) (705)

quantum smallest amount or "bundle" of energy that a wavelength of light can possess (pl. quanta) (705)

quantum chromodynamics quantum field theory that describes the strong nuclear force in terms of quantum colour (848)

quantum electrodynamics quantum field theory dealing with the interactions of electromagnetic fields, charged particles, and photons (838)

quantum field theory field theory developed using both quantum mechanics and relativity theory (837)

quantum indeterminacy probability of finding a particle at a particular location in a double-slit interference pattern (740)

quantum model combination of the particle and wave models; describes light and all other EMR as discrete bundles of energy, each of which is a massless particle that has wavelike characteristics (640)

quark any of the group of fundamental particles in hadrons (845)

R

radioactive decay series process of successive decays in which a radioactive nucleus decays into a daughter nucleus that is itself radioactive, and the daughter nucleus decays into another unstable nucleus until a stable nucleus is created (807)

radioisotope isotope that is radioactive (808)

radius of curvature (*r*) distance from the centre of curvature to the mirror surface (657)

range distance a projectile travels horizontally over level ground (105)

ray line that indicates only the direction of motion of the wave front at any point where the ray and the wave front intersect (397)

ray diagram diagram showing the result of a light ray interacting with a surface (653)

recomposition (of the spectrum) production of white light by a combination of light of all colours of the spectrum (674)

rectilinear propagation movement of light in straight lines through a uniform medium (653)

reference point arbitrarily chosen point from which distances are measured (297)

refracted ray path of a light ray after it has changed direction at an interface, due to a change in its speed (664)

refraction change in the direction of a light wave due to a change in its speed as it passes from one medium to another (666)

refractive index ratio comparing the speed of light in a vacuum to the measured speed of light in the medium (666)

relative biological effectiveness (RBE) factor indicating how much a particular type of radiation affects the human body (809)

relative motion motion measured with respect to an observer (91)

resonance increase in the amplitude of a wave due to a transfer of energy in phase with the natural frequency of the wave (418)

resonant frequencies natural frequencies of vibration of an object that will produce a standing wave pattern; at a resonant frequency, energy added is in phase with existing oscillations (418)

resultant vector sum of a series of vectors; drawn from the tail of the first vector to the tip of the last vector (71)

revolution one complete cycle for an object moving in a circular path (249)

rpm revolutions per minute; imperial unit used to measure frequency (249)

S

scalar quantity measurement that has magnitude only (6)

secondary cosmic rays shower of particles created by collisions between primary cosmic rays and atoms in the atmosphere (841)

semiconductor material that lies in the middle, between a good conductor and a good insulator; because of its nature, a semiconductor is a good conductor in certain situations, and a good insulator in other situations (514)

sievert absorbed dose of ionizing radiation that has the same effect on a person as 1 Gy of photon radiation, such as X rays or gamma rays; absorbed dose in sieverts is equal to the dose in grays multiplied by the relative biological effectiveness (RBE); unit is Sv (809)

simple harmonic motion (SHM) oscillatory motion where the restoring force is proportional to the displacement of the mass (355)

simple harmonic oscillator object that moves with simple harmonic motion (355)

Snell's Law For any angle of incidence greater than zero, the ratio $\sin \theta_i / \sin \theta_r$ is a constant for any light ray passing through the boundary between two media. (667)

solenoid electromagnet that operates a mechanical device (589)

sound barrier term applied to the increase in aerodynamic resistance as an aircraft approaches the speed of sound (433)

source charge charge that produces an electric field (546)

spectrometer device for measuring the wavelengths of light in a spectrum (773)

spectroscopy study of the light emitted and absorbed by different materials (771)

spectrum bands of colours making up white light; in order: red, orange, yellow, green, blue, and violet (675)

- **absorption line spectrum** pattern of dark lines produced when light passes through a gas at low pressure (772)
- **electromagnetic spectrum** all types of EMR considered in terms of frequency, wavelength, or energy (637)
- **emission line spectrum** pattern of bright lines produced by a hot gas at low pressure (772)

specular (regular) reflection behaviour describing parallel incident rays reflected from a flat, smooth, reflecting surface as parallel reflected rays (653)

spin quantum property resembling rotational angular momentum (842)

spring constant constant of proportionality k which appears in Hooke's Law for springs; represents the slope of the line and is measured in units of force per unit length; amount of stiffness of a spring (299)

standard model current theory describing the nature of matter and the fundamental forces (848)

static friction force exerted on an object at rest that prevents it from sliding on another object; symbol is $\vec{F}_{f_{static}}$ (171)

- **coefficient of static friction** proportionality constant relating $(F_{f_{static}})_{max}$ and F_N (182)

stationary state stable state with a fixed energy level (773)

stator fundamental component of a simple DC electric motor consisting of a frame with a coil or perma-

nent magnet to provide a magnetic field (608)

stopping potential potential difference for which the kinetic energy of a photoelectron equals the work needed to move through a potential difference V (716)

string theory theory that treats particles as quantized vibrations of extremely small strings of mass-energy (849)

superconductor conductor that has no measurable resistance at very low temperatures (515)

supernova sudden, extremely powerful explosion of a massive star (823)

synchrotron particle accelerator particle accelerator in which an advanced type of cyclotron increases the strength of the magnetic field as the particles' energy increases, so that the particles travel in a circle rather than spiralling outward (841)

system two or more objects that interact with each other (470)

- **isolated system (in the context of energy)** group of objects assumed to be isolated from all other objects in the universe (311)
- **isolated system (in the context of momentum)** when mass of a system is constant and no external net force acts on the system (470)
- **non-isolated system** system in which there is an energy exchange with the surroundings (320)

T

tangent straight line that touches a curved-line graph at only one point (24)

tension (in a rope) magnitude of a force $\vec{F}_T$ exerted by a rope on an object at the point where the rope is attached to the object (132)

test charge charge with a magnitude small enough that it does not disturb the charge on the source charge and thus change its electric field (546)

thin lens equation equation that relates object distance, image distance, and focal length of a curved lens (680)

threshold frequency minimum frequency that a photon can have to cause photoemission from a metal; symbol is f_0 (712)

torsion balance device used to measure very small forces (205)

total internal reflection reflection of all incident light back into an optically more dense medium due to inability to refract beyond the maximum angle of 90° (672)

trajectory parabolic path or motion of a projectile (103)

transmute change into a different element (798)

trough region where the medium is lower than the equilibrium position (394)

tuning (a musical instrument) changing the tension in the string of a musical instrument (424)

U

uniform circular motion motion in a circular path at a constant speed (242)

uniform motion constant velocity (motion or rest) (13)

- **non-uniform motion** acceleration (23)

uniformly accelerated motion constant change in velocity per unit time (25)

universal gravitational constant constant in Newton's law of universal gravitation that is equal to $6.67 \times 10^{-11}\ \text{N}\bullet\text{m}^2/\text{kg}^2$; symbol is G (204)

universal wave equation relationship between the speed, frequency, and wavelength of a wave: $v = f\lambda$ (408)

V

Van de Graaff particle accelerator particle accelerator in which a moving belt transfers charge to a hollow, conductive sphere, building up a large potential difference that propels ions through an accelerator chamber (841)

vector quantity measurement that has both magnitude and direction (6)

velocity rate of change in position; includes magnitude (speed) and direction (12)

- **air velocity** object's velocity relative to still air (92)
- **ground velocity** velocity relative to an observer on the ground (92)
- **instantaneous velocity** moment-to-moment measure of an object's velocity (24)
- **wind velocity** velocity of the wind relative to the ground (92)

vertex (V) geometric centre of the curved mirror surface (657)

W

wave disturbance that moves outward from its point of origin transferring energy through a medium by means of vibrations (394)

- **bow wave** V-shaped wave produced as a boat moves through water or an airplane moves through the atmosphere (433)
- **electromagnetic wave** periodic variation in perpendicular electric and magnetic fields, propagating at right angles to both fields (643)
- **incident wave** wave front moving out from the point of origin toward a barrier (395)
- **longitudinal wave** wave with the motion of the medium being parallel to the motion of the wave (401)
- **reflected wave** wave front moving away from a barrier (395)
- **shock wave** strong compression wave produced as an aircraft exceeds the speed of sound (433)
- **standing wave** condition in a spring or other medium in which a wave seems to oscillate around stationary points called nodes; wavelength of a standing wave is the distance between alternate nodes or alternate antinodes (417)
- **transverse wave** wave with the motion of the medium being perpendicular to the motion of the wave (401)

wave amplitude distance from the equilibrium position to the top of a crest or the bottom of a trough (395)

wave front imaginary line that joins all points reached by the wave at the same instant (395)

wave model describes EMR as a stream of transverse waves radiating outward from a source (639)

wave–particle duality light has both wave-like and particle-like properties (726)

wave train series of waves forming a continuous series of crests and troughs (395)

wavelength distance between two points on a wave that have identical status; usually measured from crest to crest or from trough to trough (395)

waves in phase occurs when crests or troughs from two waves occupy the same point in the medium; produces constructive interference (395)

waves out of phase occurs when a crest from one wave occupies the same point in the medium as a trough from a second wave; produces destructive interference (416)

weight gravitational force exerted on an object by a celestial body; symbol is $\vec{F}_g$ (198)

- **apparent weight** negative of the normal force acting on an object; symbol is $\vec{w}$ (224)
- **true weight** gravitational force acting on an object that has mass (222)
- **true weightlessness** situation in which $\vec{w} = 0$ for an object and $\vec{F}_g = 0$ on the object (228)

work measure of the amount of energy transferred when a force acts over a given displacement; calculated as the product of the magnitude of applied force and the displacement of the object in the direction of the force (293)

work–energy theorem work done on a system is equal to the sum of the changes in the potential and kinetic energies of the system (307)

work function minimum energy that a photon can have to cause photoemission from a metal; specific for every metal; symbol is W (713)